

# Emission Factors for Russian Car Fleet Determined from Backward Dispersion Calculations

A contribution to subproject SATURN

Alexander Ziv<sup>1</sup>, Ruwim Berkowicz<sup>2</sup>, Ekaterina Yakovleva<sup>1</sup>,  
Eugene Genikhovich<sup>1</sup>, Finn Palmgren<sup>2</sup>

<sup>1</sup>Main Geophysical Observatory, St. Petersburg, Russia

<sup>2</sup>National Environmental Research Institute, Roskilde, Denmark

e-mail: adz@main.mgo.rssi.ru

## Summary

The problem of obtaining the realistic values of the emission factors for different types of vehicles is considered in this work. Concentration data collected during December 1998 – May 2001 in St. Petersburg at Pestelya Street, which could be considered as a street canyon, are used together with two air pollution models – Danish OSPM and Russian OND-86. These models are of different types: the first one predicts the actual concentrations in a street canyon for prescribed (actual) governing meteorological parameters, the second one estimates the 98<sup>th</sup> percentiles of the concentrations with account for the building downwash effects. Concentrations of benzene, toluene, NO and NO<sub>2</sub>, ozone and SO<sub>2</sub> were measured by two DOAS instruments installed at two (street and roof) levels.

The OSPM and OND-86 calculations were firstly carried out using emission factors recommended by the Russian national guideline. The results show relatively good agreement from the point of the correlation but significant discrepancy in scale. To estimate the actual emission factors we considered the approximation of the normalised observed time series of differences D between street level and roof level concentrations by the following sum of four terms:

$$\frac{D}{C_1} \approx E_c * T_c + E_v * T_v + E_b * T_b + E_t * T_t \quad (1)$$

where  $\tilde{N}_1$  is concentration calculated assuming that the emission is equal to one; scalars E denote unknown emission factors (in g/km); time series T mean the traffic intensity multiplied by the product of the speed correction factor and corresponding unit conversion coefficient; subscripts c, v, b, t correspond to different types of vehicles (passenger cars, vans, buses and trucks). Emission factors are obtained then from minimization of the mean squared modelling error subject to additional constraints, which make the solution more stable. In case of the OSPM model these errors were considered for the each measurement. In case of OND-86 model we considered sets of measurements corresponding to different times of day and determined 98<sup>th</sup> percentiles for the each of these sets.

Both methods of the estimation of the emission factors were applied to benzene and NO<sub>x</sub>. The results obtained by OSPM demonstrated significant discrepancy with the abovementioned reference values, and this discrepancy should be specially investigated. Emission factors obtained by the OND-86 model were found between the reference values and OSPM estimates.

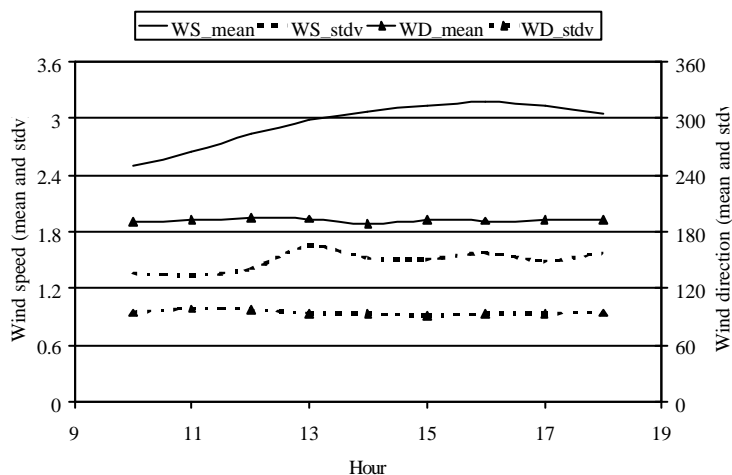
## Introduction

In the framework of the Danish-Russian project “Monitoring and analysis of air pollution in St. Petersburg”, two DOAS instruments were installed in St. Petersburg on Pestelya Street, which could be considered as a street canyon (Genikhovich, et al., 2000). Concentrations of benzene, toluene, NO and NO<sub>2</sub>, ozone and SO<sub>2</sub>, collected during December 1998 – May 2001 in St. Petersburg at Pestelya Street, which could be considered as a street canyon, were measured by instruments installed at two (street and roof) levels. Continuous meteorological measurements at Pestelya Street started first in September 2000. Concentrations, measured before this time, were analysed using data obtained from the meteorological mast located about 5 km from the DOAS instruments. Comparison of the wind directions and wind speeds at these two sites measured during five-months period from September 2000 has shown that they are in a good agreement but the factor of 0.8 was obtained from the regression analysis for correcting wind speed at the remote mast. There is also additional information about the traffic intensity measured manually for different types of vehicles.

The car fleet consists mainly of cars of different types and ages, which can be hardly characterised by some definite emission factors. Therefore in the current study we used concentration data obtained during this project to estimate emission factors for different types of vehicles using Danish Operational Street Pollution Model (OSPM) (Berkowicz et al., 1997b) and Russian OND-86 model (Berlyand et al., 1987).

## Results

The OSPM and OND-86 models are of different types: the first one predicts the actual concentrations in a street canyon for prescribed (actual) governing meteorological parameters, the second one estimates the 98<sup>th</sup> percentiles of the concentrations with account for the building downwash effects. The OSPM calculations were firstly carried out using the



**Figure 1:** Time variation of the wind speed and wind direction

emission factors from the Russian national guideline (Milyaev et al., 1999). Coefficients of correlations between calculated with these emission factors and measured concentrations are rather high but there is a significant discrepancy in scale. In order to correct this discrepancy, the actual emission factors  $E$  were obtained from (1) considered as a regression equation. In case of OSPM the mean squared modelling error was

minimised subject to following constraints: both means and 98<sup>th</sup> percentiles of the observed and modelled values should differ less than 10%. In case of OND-86 model we considered subsets of measurements corresponding to different times of day and determined 98<sup>th</sup> percentiles for the each of these subsets. Actually, it can be done only if we suppose that the variety of corresponding meteorological conditions is more or less the same for the each hour during the daytime. From Fig. 1 it can be seen that at least the average values and standard deviations of the wind speed and wind directions do not differ significantly. It is evident also that the value  $\tilde{N}_1$  in (1) is the same for the different hours.

It should be noted that daily variations of traffic intensities for different types of vehicles are rather similar, and it makes statistically not stable the problem of determining all four emission factors in Eq. 1. That is why we estimated the emission factors for two groups of vehicles combining passenger cars and vans in one of them and trucks and buses in another. In this case we can rewrite Eq. 1 as follows:

$$D(h)/C_1 * T_1(h) = E_1 + E_2 * \left( T_2(h)/T_1(h) \right) \quad h=10,11,\dots,18 \quad (2)$$

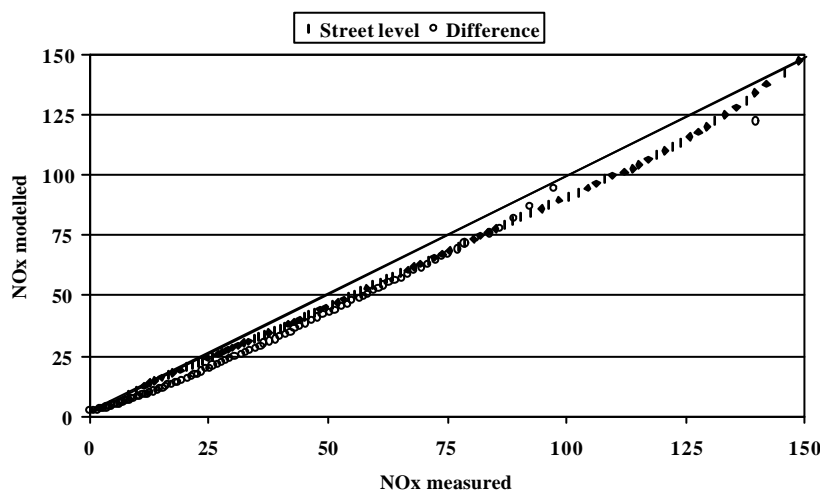
If  $E_1$  and  $E_2$  are determined from the regression line, the ratio between these emission factors does not depend on the model value  $C_1$ .

The results of the estimation of emission factors using both models are presented in Table 1 (experimental estimates) together with those taken from Milyaev et al., (1999) (reference values).

**Table 1:** Emission factors (g/km) for NO<sub>x</sub> and benzene

	<i>Cars</i>	<i>Vans</i>	<i>Trucks</i>	<i>Buses</i>
<b>NO<sub>x</sub></b>				
Reference value	1.8	2.9	6.45	6.65
<i>Experimental estimate</i> <i>OSPM</i>	1.44	1.44	3.90	3.90
<i>OND-86</i>	1.63	1.63	3.14	3.14
<b>Benzene</b>				
Reference value	0.63	0.45	0.91	0.98
<i>Experimental estimate</i> <i>OSPM</i>	0.16	0.16	0.44	0.44
<i>OND-86</i>	0.32	0.32	1.33	1.33

The quintile – quintile plot for calculated from OSPM with corrected emissions and measured street-level concentrations is shown on Fig. 2. It is evident that distributions of the modelled and measured concentrations are rather similar but the model slightly underestimates street - level values.



**Figure 2:** Quintile – quintile plot for NO<sub>x</sub>

When using the OND-86 model, 98<sup>th</sup> percentiles were fitted for each whole hour of the day. It was found that these percentiles for different hours in daytime are rather close. Therefore, one can expect that there should be no significant diurnal variations in "hourly emission factors", which could influence our results.

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## Conclusions

Model calculations with OSPM using reference values of the emission factors accepted in Russia revealed satisfactory correlations of the modelled and observed concentrations but difference in their levels. The special techniques was developed and applied to the estimation of these emission factors with the use of two models – OSPM and OND-86. The results obtained demonstrated significant discrepancy with the abovementioned reference values, and this discrepancy should be specially investigated. Calculations with the OSPM model using obtained emission factors showed that the probability distributions of calculated and measured concentrations were close. Correlation coefficients for the scatterplots (observed versus modelled concentrations) of NO<sub>x</sub> and benzene are 0.68 and 0.7, respectively. However, if we compare concentrations observed at the street level with the sum of those modelled at the street level measured at the roof level, the correlation coefficients for the scatterplots are equal 0.89 and 0.82. . Emission factors obtained by the OND-86 model were found between the reference values and OSPM estimates. Calculations of 98<sup>th</sup> percentiles using both model with adjusted emission factors gave almost the same results.

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